sPHENIX Project Overview

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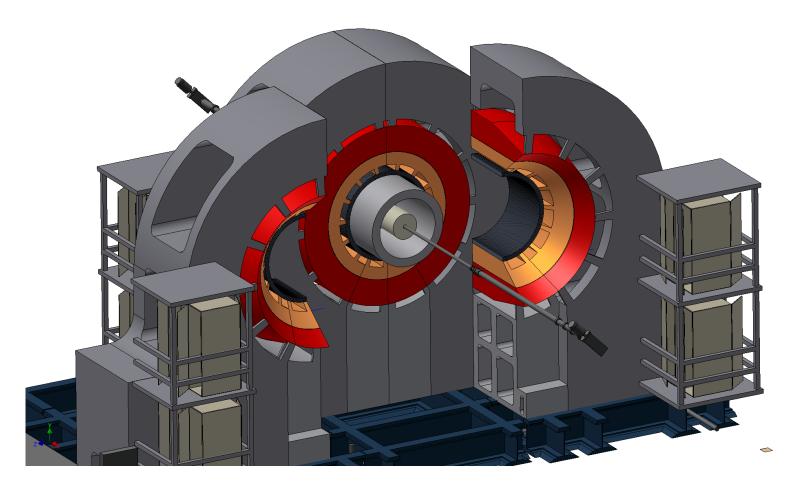


What is sPHENIX?

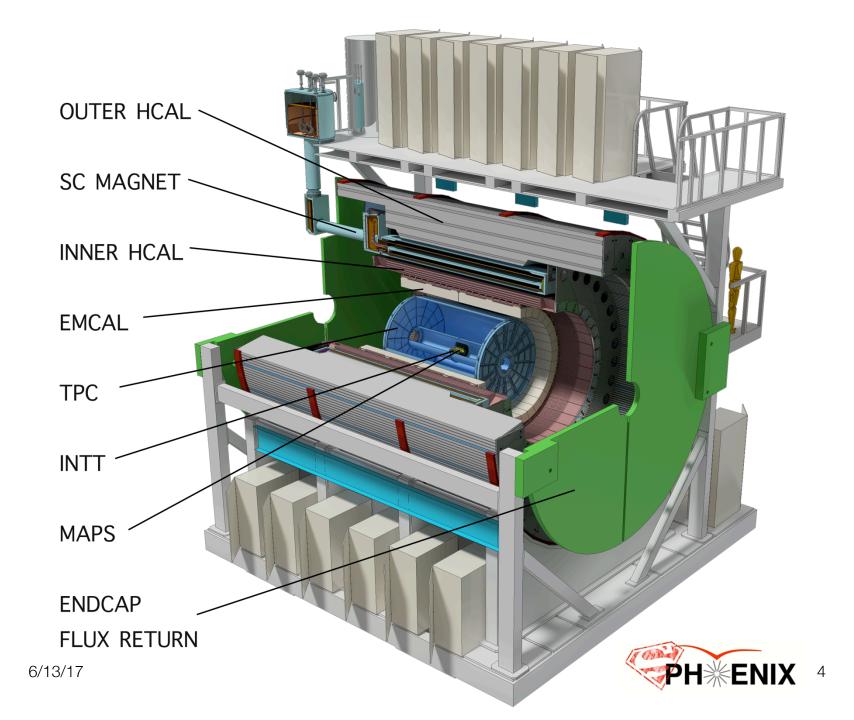
- sPHENIX is a proposal for a major upgrade to the PHENIX detector capable of making high statistics measurements of:
 - Jets with tracking and calorimetric reconstruction
 - Jets correlations
 - Upsilon states
- A proposal in July 2012 led to the DOE reviews in July 2014 and May 2015 affirmed the science case which was subsequently included in the September 2015 NSAC Long Range Plan and led to a CD-0 approval September 2016
- A new sPHENIX collaboration was formed in December 2015 which continues to grow to realize this detector and harvest its physics



sPHENIX 2012

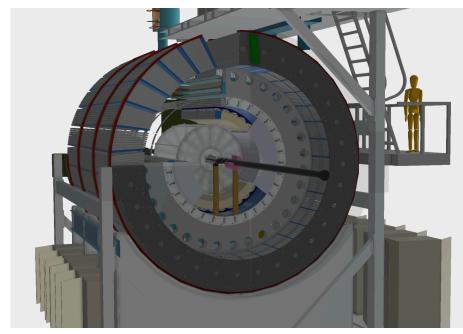






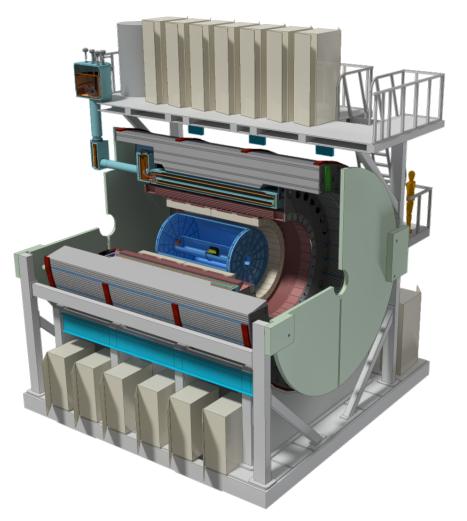
sPHENIX design

- 3D model of the detector is available to you:
 - In docDB:
 https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?
 https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?
 https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?
 https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?
 https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?
 - In Fusion 360 (free online viewer):http://a360.co/2qUhmke
- Make your own views





Scope of sPHENIX MIE



$\overline{ ext{WBS}}$	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

$\overline{ ext{WBS}}$	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

WBS	Parallel Activities
1.11	Intermediate Silicon Strip Tracker
1.12	Monolithic Active Pixel Sensors



What are we building?

- Our planning is to construct a full baseline sPHENIX detector, although not all parts of the project are directly under our control
 - Full calorimeter scope (EMCAL, Inner and Outer HCAL)
 - Full tracking scope
 - TPC
 - INTT
 - MVTX
- Other detectors (Forward sPHENIX, TOF) have not completed making a physics case to funding agencies, we will try and keep our options open, but sPHENIX resources are stretched thin
- We have attempted to maintain the viability of the sPHENIX detector as a detector at EIC



Department of Energy FY 2018 Congressional Budget Request



Science

(Vol 4)

2018 budget proposal

https://energy.gov/cfo/downloads/fy-2018-budget-justification

phenomena that have emerged in quark-gluon plasma formation. In FY 2018, researchers at RHIC will implement significant accelerator improvements developed over the past couple of years to increase luminosity, enabling a campaign to search for a critical point in the phase diagram of nuclear matter the following year. Efforts will continue, within available, existing resources, to enhance the capabilities of the STAR detector, and continue limited advanced engineering and design activities for an upgrade of the PHENIX detector to sPHENIX. The subprogram will also support limited short and mid-term accelerator R&D at RHIC in critical areas that may include the cooling of high-energy hadron beams, high intensity polarized

delayed, but will continue funding these improvements as funding permits. Within available funding, a small effort will also continue on advanced conceptual engineering and design efforts associated with the planned upgrade of PHENIX to "super PHENIX" or sPHENIX. sPHENIX will enable scientists to study how the strongly interacting QGP liquid arises from the weakly interacting quarks and gluons from which it is formed.



When will sPHENIX get CD-1?

- Our present guidance is that we would not get a CD-1 review/approval until after the FY2018 budget settles down, the timescale for that is after March 2018
- sPHENIX post-CD-1 is not in the FY2018 budget plan, so we are not likely to have a CD-1 review/approval until late in 2018

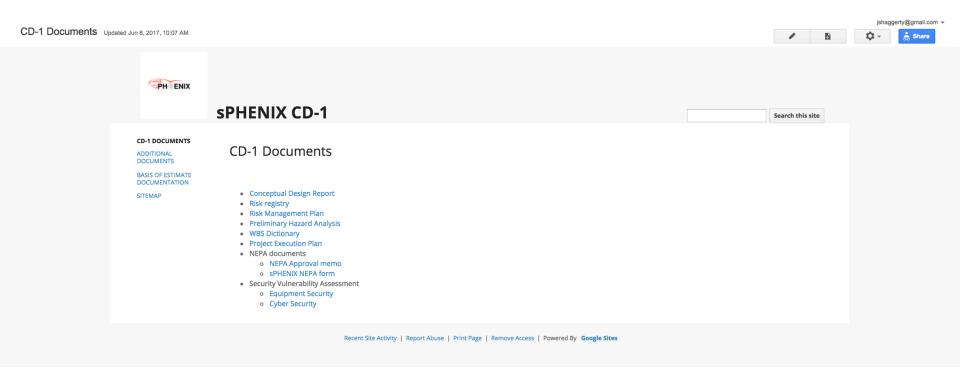


Project timetable

- We had a very useful and largely positive internal sPHENIX "Document Review" June 5-6
 - Organized by Deputy Director Tribble
 - Subsystem managers did a **lot** of work to prepare for this review, and all did a great job in the review
- MVTX BNL review July 10-12
- sPHENIX "Director's Review" August 2-4 to be chaired by Jay Marx
 - Practices for this currently planned for July 6-7 and July 12-14
- DOE OPA CD-1 review will likely not be Nov 7-9



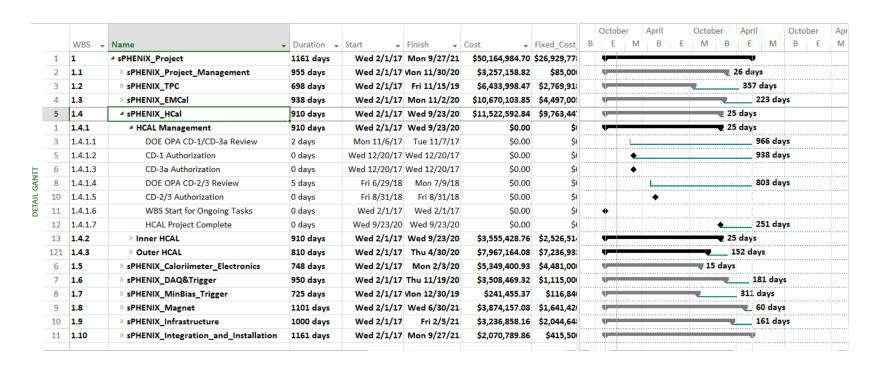
June 5-6 CD-1 Document Review



https://sites.google.com/site/sphenixcd1/



Project plan and Resource Loaded Schedule

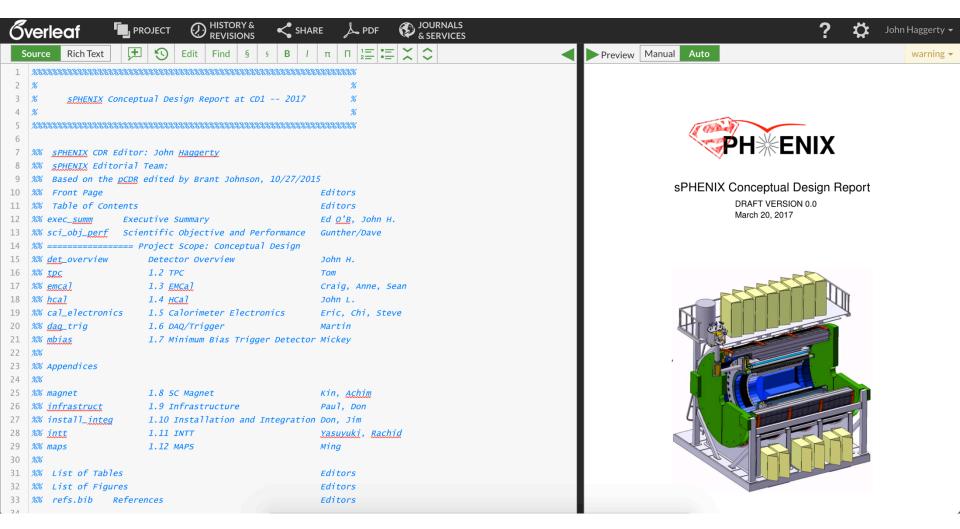


- 2000 line Project plan and budget developed by L2 Managers for the Document Review
- Bob Ernst will summarize the plan in the next talk



Full instructions: https://wiki.bnl.gov/sPHENIX/index.php/CDR

https://www.overleaf.com/8705585kvywfxxqyftr





Lessons learned from Document Review

- The Level 2 managers did a great job pulling the Project information together
- The cost and schedule data look pretty well organized and reasonable, but we need some thorough checking for consistency to look good in a "drill-down"
- The CDR looks basically sound, but it needs to incorporate the current knowledge from simulation
- The lab has assigned us a consultant to put our cost and schedule into Oracle Primavera ("P6"), essentially required for CD-1

Example of cost and schedule in P6

DRAFT Schedule		1		1=	1	sPHENIX WBS Detai			1	1_
	Activity Name	Original Duration	Start	Finish	Budgeted Labor Units	Budgeted Labor Cost	Budgeted Nonlabor Units	Budgeted Nonlabor Cost	Budgeted Total Cost	Resources
s105600	Produce TPC GEM foils (includes Technician fees)	125	01-Nov-18*	03-May-19	0	\$0.00	135216	\$164,860.76	\$164,860.76	Material (Purchase >\$25k<\$2M)
s105650	GEM Production Complete	0	06-May-19	06-May-19*	0	\$0.00	0	\$0.00	\$0.00	
S.1.2.1.7 TPC Hig	gh Voltage System	184	07-Feb-18	29-Oct-18	256	\$9,826.39	52100	\$65,346.80	\$75,173.19	
s105700	Select TPC GEM HV Power Supplies	10	07-Feb-18*	21-Feb-18	80	\$0.00	0	\$0.00	\$0.00	SCI3_SBU
s105750	Procure TPC GEM HV Power Supplies	40	31-Aug-18*	29-Oct-18	32	\$3,291.68	36500	\$44,044.55	\$47,336.23	TECH3 Other, Material (Purchase >\$25k<\$2M)
s105800	Procure TPC Membrane HV Cable	40	22-Feb-18*	18-Apr-18	32	\$3,243.03	600	\$811.13	\$4,054.16	TECH3 Other, Material (Purchase <\$25k)
s105850	Select TPC Membrane HV Power Supply	10	07-Feb-18*	21-Feb-18	80	\$0.00	0	\$0.00	\$0.00	SCI3_SBU
s105900	Procure TPC Membrane Power Supply	40	31-Aug-18*	29-Oct-18	32	\$3,291.68	15000	\$20,491.13	\$23,782.80	TECH3 Other, Material (Purchase <\$25k)
S.1.2.1.8 TPC As	sembly	219	07-Jan-19	19-Nov-19	3536	\$272,228.08	0	\$0.00	\$272,228.08	
s105950	Install TPC Modules into Field Cage	125	07-Jan-19*	03-Jul-19	2496	\$200,419.46	0	\$0.00	\$200,419.46	SCI3_SBU, TECH3 Other
s106000	Install TPC Electronics		01-Aug-19*		208		0	\$0.00		SCI3_SBU, TECH3 Other
s106050	Test TPC Prior to Installation		15-Aug-19*		832			\$0.00		SCI3_SBU, TECH3 Other
s106100	TPC Ready to Install		19-Nov-19		0	*****	0		, ,	
.1.2.2 TPC R1 Mod			04-Dec-17		6720		82171	\$111,833.88		
S.1.2.2.1 TPC R1	1 Module Factory Preparation		04-Dec-17		640		20020	\$27,064.64		
s106150	Prepare TPC R1 Factory Clean Facility		04-Dec-17*		320		8020	\$10,842.08		PROF3_PNPI, Material (Purchase <\$25k)
s106200	Prepare TPC R1 Factory Tooling	40	04-Dec-17*	31-Jan-18	320	\$35,848.28	12000	\$16,222.56	\$52,070.84	PROF3_PNPI, Material (Purchase <\$25k)
S.1.2.2.2 TPC R1	1 Pre-Production Module	90	07-Feb-18	15-Jun-18	896	\$43,868.41	9418	\$12,732.01	\$56,600.41	
s106250	Design TPC R1 Pre-Production Module (strongback, frame, grid, pad, GEMs)		07-Feb-18*		320	\$17,924.14	0	\$0.00		SCI3_SBU, PROF3 Other
s106300	Procure TPC R1 Pre-Production Module Stongbacks	30	08-Mar-18*	18-Apr-18	24	\$2,432.27	1200	\$1,622.26	\$4,054.53	TECH3 Other, Material (Purchase <\$25k)
s106350	Procure TPC R1 Pre-Production Module Frames	30	08-Mar-18*	18-Apr-18	24	\$2,432.27	1000	\$1,351.88	\$3,784.15	TECH3 Other, Material (Purchase <\$25k)
s106400	Procure TPC R1 Pre-Production Module Grids	20	08-Mar-18*	04-Apr-18	160	\$16,215.17	500	\$675.94	\$16,891.11	TECH3 Other, Material (Purchase <\$25k)
s106450	Procure TPC R1 Pre-Production Module Pad Planes	30	08-Mar-18*	18-Apr-18	24	\$2,432.27	1718	\$2,322.53	\$4,754.80	TECH3 Other, Material (Purchase <\$25k)
s106500	Procure TPC R1 Pre-Production Module GEMs	30	08-Mar-18*	18-Apr-18	24	\$2,432.27	5000	\$6,759.40	\$9,191.67	TECH3 Other, Material (Purchase <\$25k)
s106550	Assemble TPC R1 Pre-Production Module in TPC R1 Factory	30	19-Apr-18*	31-May-18	240	\$0.00	0	\$0.00	\$0.00	SCI3_PNPI
s106600	Test TPC R1 Pre-Production Module	10	01-Jun-18*	14-Jun-18	80	\$0.00	0	\$0.00	\$0.00	SCI3_PNPI
s106650	TPC Module Production Readiness Review	0	15-Jun-18	15-Jun-18*	0	\$0.00	0	\$0.00	\$0.00	
S.1.2.2.3 TPC R1	1 Module Production	199	31-Aug-18	20-Jun-19	5184	\$220,423.54	52733	\$72,037.23	\$292,460.78	
s106700	Procure TPC R1 Module frames		31-Aug-18*		64		13333	\$18,213.88		PROF4 Other, TECH3 Other, Material (Purchase <\$25k)
s106750	Procure TPC R1 Module strongbacks	40	31-Aug-18*	29-Oct-18	64	\$7,518.01	15400	\$21,037.56	\$28,555.56	PROF4 Other, TECH3 Other, Material (Purchase <\$25k)
s106800	Procure TPC R1 Module Pad Planes	40	31-Aug-18*	29-Oct-18	32	\$3,291.68	20000	\$27,321.50	\$30,613.18	TECH3 Other, Material (Purchase <\$25k)
s106850	Procure TPC R1 Module Grids	40	31-Aug-18*	29-Oct-18	32	\$3,291.68	4000	\$5,464.30	\$8,755.98	TECH3 Other, Material (Purchase <\$25k)
s106900	Build TPC R1 Modules	125	06-Dec-18*	05-Jun-19	2496	\$99,402.09	0	\$0.00	\$99,402.09	SCI3_PNPI, TECH3_PNPI
s106950	Test TPC R1 Modules		20-Dec-18*		2496		0	\$0.00		SCI3_PNPI, TECH3_PNPI
s107000 TPC R1 Production Ends			20-Jun-19		0		0	\$0.00		
S.1.2.3 TPC R2 Modules				20-Jun-19	624			\$111,833.88		



© Oracle Corporation

Solenoid magnet

- High resolution tracking translates to high field
 - 1.5 T
 - 2.8 m bore
 - 3.8 m long
- BaBar solenoid arrived at BNL in February 2015
 - Low field test March 2016
 - Preparing now for high field test
 September 2017
- Cryo, power supply, and quench protection for 1008 under development
- By this time next year, we aim to have tested the magnet at full field





Progress on magnet

- Kin Yip is L2 manager
- Valve box extension is complete
- Power supply tested
- Control and monitoring systems being developed
- High field test flux return nearing completion
- Solenoid to be moved into flux return in the next couple of weeks
- High field test planned for September



Calorimeter beam tests





February 2014
Proof of principle

April 2016 η~0 sPHENIX geometry

February 2017 $\eta \sim 0.9$

https://arxiv.org/abs/1704.01461

Thanks to the Megan, Jin, Abhisek, Ron, and Virginia



Calorimeter beam tests at Fermilab

- Preparations have begun for the next round of beam tests, tentatively scheduled for Feb 21-Mar 28, 2018
- This test will be pre-production electronics, value engineered Inner HCAL, final HCAL tiles, EMCAL towers that incorporate our best knowledge of how to make the light collection uniform



HCAL sector -1



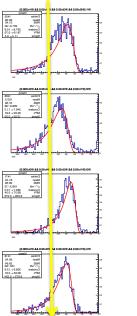


Inner HCAL at TSI

Outer HCAL at Strecks



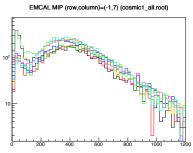
DCM II





CALADC

EMCAL





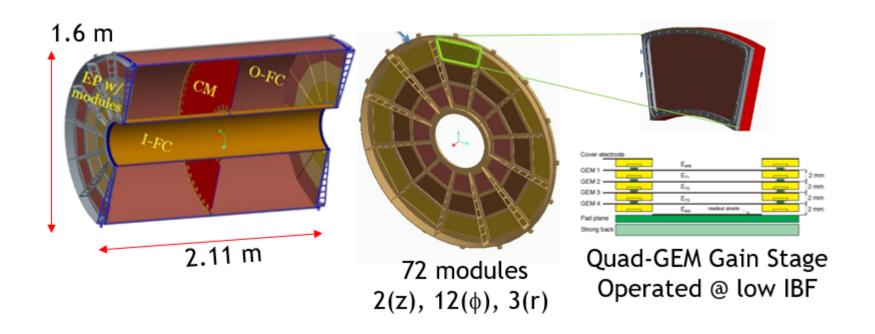
IHCAL

TPC key features

- Compact—outer radius 80 cm
- 3 (radial) x 12 (azimuthal) GEM chambers per end
- FEE board being developed around SAMPA ASIC to be used by ALICE and STAR iTPC (no new ASIC development)
- Fast gas low diffusion to achieve position resolution < 200 μ
- Field distortions minimized by
 - Minimize Ion Back Flow by judicious choice of electric field between GEM foils, pioneered by ALICE
 - Gas choice (low mass, fast drift)
 - High electric field
 - Inner field cage 30→20 cm
- Continuous readout

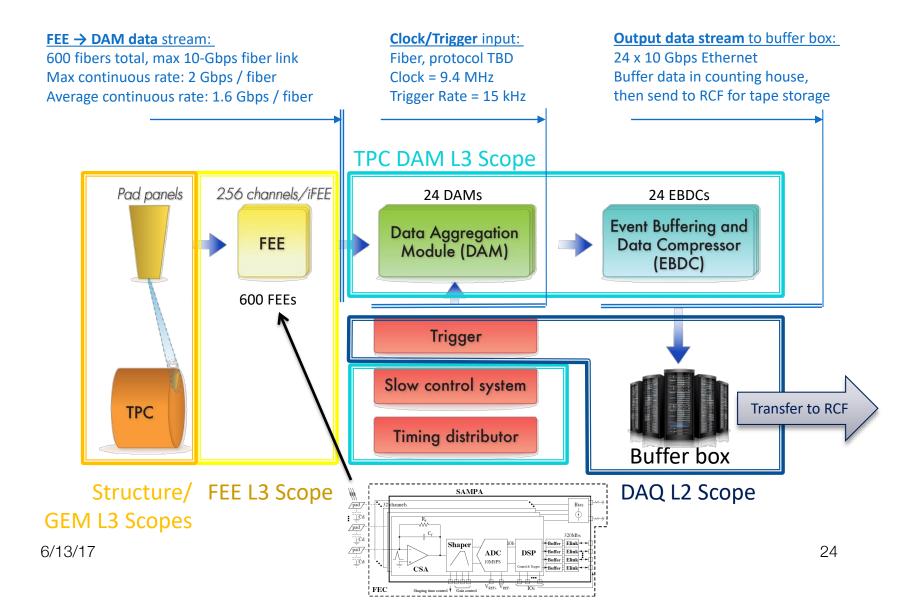


TPC detector overview

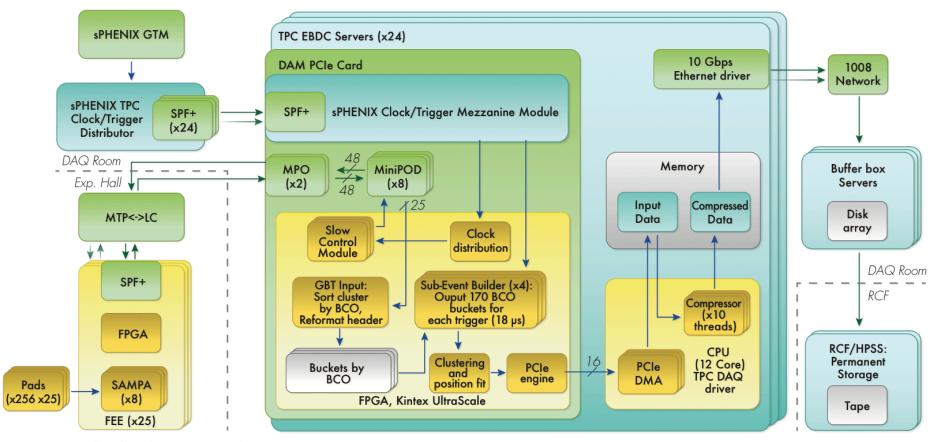




TPC electronics overview



DAM and EBDC as envisioned using ATLAS FELIX board



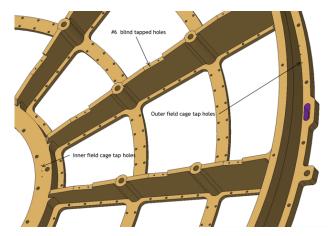




Next steps in TPC

- Mechanical design and analysis very advanced
- Full size prototype under construction at SBU
- Up to 80 kV high voltage material tests
- Attempt to optimize pad design
- Complete and test prototype field cage
- Prototype FEE card
- Set up tests with FELIX board
- Inner Region Integration Task Force
- Simulations
- Consider how we can do a truly comprehensive system test



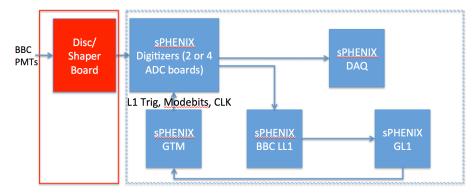




Minimum Bias Detector

- This detector was the PHENIX BB counter and we expect to use it in sPHENIX
- Existing electronics could be resurrected, but development of a relatively simple shaper board would allow us to use the new calorimeter electronics
- PHENIX BB operated in a magnetic field, some testing and judicious choice of location is needed
- Trigger based on calorimeter trigger will be needed







DAQ

- Calorimeter readout uses a modest DCM II's developed for PHENIX, as does INTT
- Tests with DCM II indicate 15 kHz/90% live should not be a problem
- Modest redesign of timing system and trigger manager ("GL1" in PHENIX parlance)
- TPC readout has been described, and provides a significant challenge in data volume and rates
- Data logging rate feasible today, likely to be even more feasible in five years



Summary

- We are building sPHENIX with a philosophy of prototype/test/ simulate/review to be as prepared as possible for first collisions
- Calorimeter and calorimeter electronics very far along the development arc and have achieved required performance; could be ready for production next year, with experience of constructing and handling full size prototypes
- The magnet will be tested at full field in the next few months
- The TPC and the TPC electronics are deep into development, and rely on technology being developed for ALICE and STAR
- The MBD detector exists and needs a modest amount of testing and development
- DAQ and Trigger build on PHENIX experience, but need the first round of hardware to establish that the reference design is practical



Issues and concerns

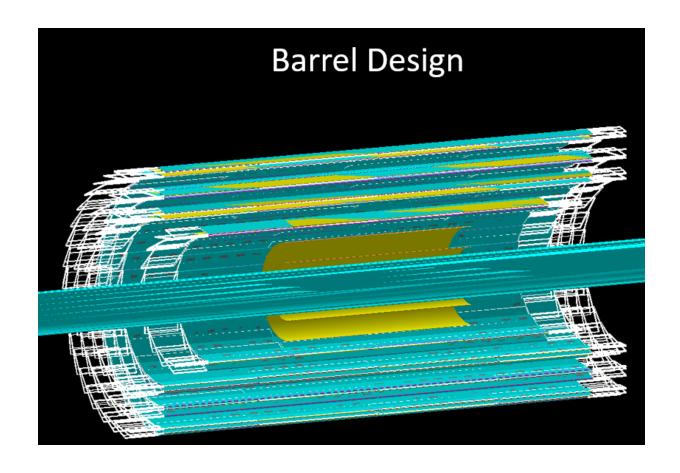
- Engineering and design effort is at a premium, we have to be careful to use our resources carefully
- We need system tests as soon as we can do them of TPC, INTT, and MAPS
- The simulation software has matured a lot in the past year thanks to the efforts of many people like Chris, Jin, Tony, Haiwang, Christof, Carlos, Veronica and many others
 - Need to keep moving forward
 - Need physics analysis notes based on MC
- Better simulation results is the biggest need for the CDR
- The project plan needs to be gone over with a fine tooth comb to make sure it makes sense and add things that we've missed



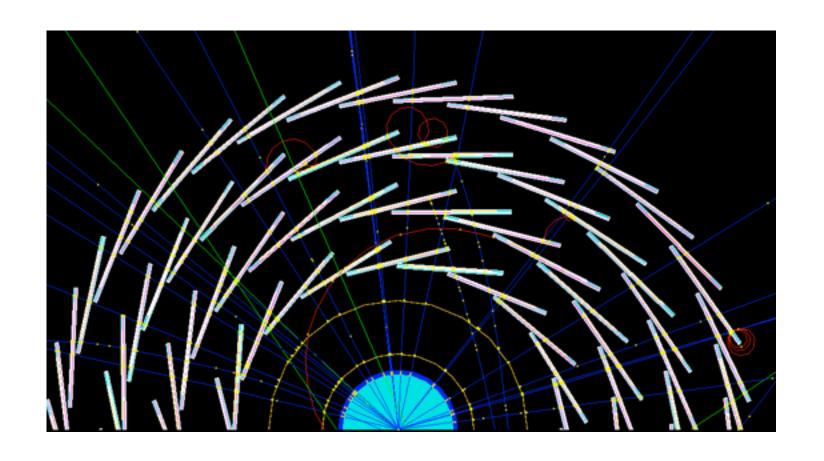
BACKUP MATERIAL



INTT



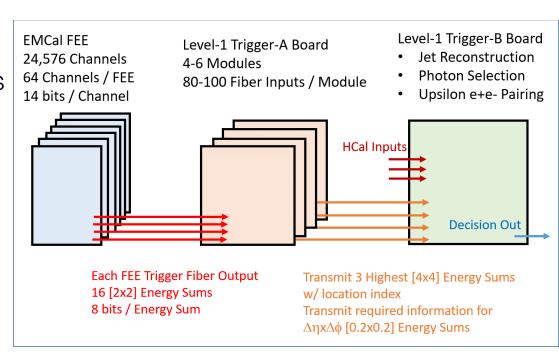






Trigger

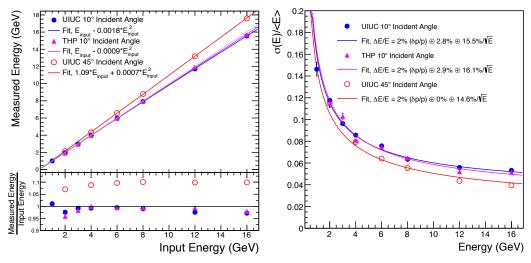
- Calorimeter electronics is designed with hooks on the backplane for trigger primitives
- Trigger studies/ simulation under way





Measured Energy (GeV) UIUC 10° Incident Angle UIUC 10° Incident Angle Fit, E_{input} - 0.0017*E²_{input} Fit, $\Delta E/E = 2\% (\delta p/p) \oplus 1.6\% \oplus 12.7\% / \sqrt{E}$ THP 10° Incident Angle Fit, ΔE/E = 2% (δp/p) ⊕ 0% ⊕ 14%/¶E Fit, E_{input} - 0.0007*E_{input} ² 10° Simulation: $\Delta E/E = 2\% (\delta p/p) \oplus 1.5\% \oplus 11.4\%/\sqrt{E}$ UIUC 45° Incident Angle 0.14 UIUC 45° Incident Angle Fit, 1.08*E_{input} + 0.0008*E_{in} Fit, ΔE/E = 2% (δp/p) ⊕ 0% ⊕ 12.1%/√E - 45° Simulation: ΔE/E = 2% (δp/p) ⊕ 0.1% ⊕ 11.0%/√E 0.08 0.06 0.04 0.02 Input Energy (GeV) Energy (GeV)

Tower center

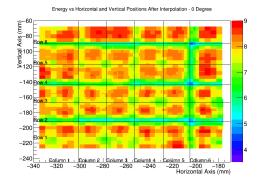


Entire tower

PH*ENIX

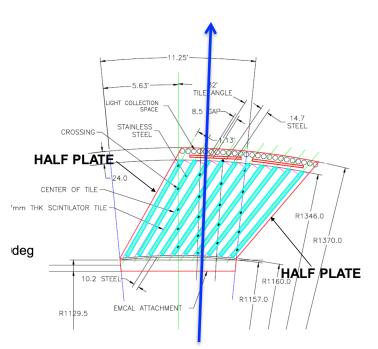
EMCAL η~0 beam test

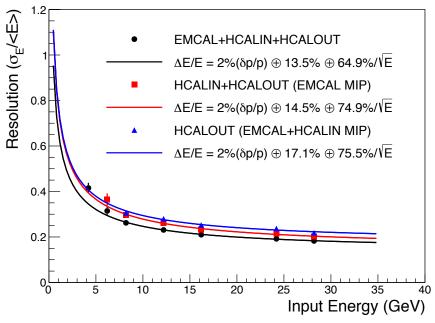
The beam tests taught us to be more meticulous about uniformity and boundaries and ways to correct for it... systematic mapping in η~0.9 beam test



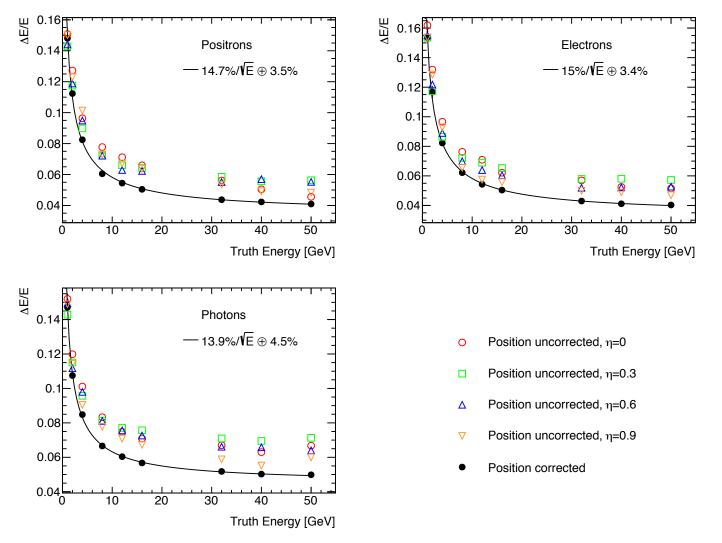
HCAL η~0 beam test

 Learned calibration techniques, energy response uniformity in tiles









EMCAL performance predictions in simulation from Joe Osborn

